



Design of a Proning Mattress to Increase Oxygen Saturation in Patients With Respiratory Problems

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Abstract

The correct pronation position has been proven to increase oxygen saturation in patients with respiratory problems. However, setting the pronation position using pillow support at several points on the patient's body allows for inaccuracies due to differences in pillow size and the shift of the pillow when used, so an existing pronation position control device is needed. Precise, safe, comfortable, and can be used directly by patients. This research aims to create and develop a "marning" prototype (proning mat) to make it easier to perform the proning position. The research method was carried out by making a proning mat, which was designed, taking into account the anatomy and ergonomics of the body so that it was very precise in increasing oxygen saturation. The mattress prototype was tested for its effectiveness on shortness of breath patients to see an increase in oxygen saturation. This technology model has been successfully prototyped and proven to increase oxygen saturation in 80% of patients with respiratory disorders. This mattress is designed to replace the pillows in common proning positions. The mattress design takes into account the anatomy and ergonomics of the body with precise measurements. This innovation allows patients to carry out the correct, comfortable proning position and is also very effective and efficient because it can be used directly independently. However, the tool developed needs to be refined in subsequent research, to get a tool that is lighter so that it is easy to move and carry anywhere.

Introduction

In 2019, Indonesia and almost the entire world were shocked by the presence of a new virus, namely COVID-19. COVID-19 is an atypical acute respiratory infection caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Parasher, 2021; Peng et al., 2020). Common symptoms of COVID-19 are cough, fever, fatigue, whole-body pain, and shortness of breath (Esakandari et al., 2020). Patients with moderate symptoms generally experience shortness of breath, increased respiratory rate, and decreased oxygen saturation (SpO₂ 90-95%). Patients with severe disease with moderate symptoms plus one of the following symptoms: respiratory rate >30

times/minute, severe respiratory distress, or SpO₂ <90% (WHO, 2021; Wu & McGoogan, 2020). The progression of COVID-19 is quite high, so some patients with mild symptoms quickly progress to severity (Wang et al., 2021). Patients with mild symptoms can carry out self-quarantine with several supportive therapies. Patients with moderate and severe symptoms should be treated in health facilities with appropriate monitoring (WHO, 2021). In patients with symptoms of respiratory failure, oxygen therapy is the first treatment and is given based on needs and appropriate methods (WHO, 2021).

The proning position is very familiar and is recommended for treating respiratory

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symptoms in COVID-19 patients, however, this proning position is also very likely to help increase oxygen saturation in patients with complaints of shortness of breath due to other diseases such as asthma, heart disease, and other diseases. The pronated position is one of the interventions applied to acute respiratory distress syndrome (ARDS) patients with invasive mechanical ventilation. The pronated position improves lung homogeneity, gas exchange, and respiratory mechanisms, which allows for a reduction of ventilation intensity and reduces lung injury in ARDS patients with invasive mechanical ventilation therapy (Guérin et al., 2020). The proning position (PP) was first introduced in 1976 (Piehl & Brown, 1976) and has been used for more than 40 years to improve oxygenation (Juarez Villa et al., 2020). The pronation position has been implemented in COVID-19 patients who are conscious but have decreased oxygenation and are receiving non-invasive oxygen therapy. The results show that the pronation position improves oxygenation (SpO₂, PaO₂, and PaO₂/FiO₂) and reduces the need for invasive intubation and ventilation in COVID-19 patients (Anand et al., 2021; Bamford et al., 2020; Caputo et al., 2020; Chad & Sampson, 2020; Coppo et al., 2020; Damarla et al., 2020; Ponnappa Reddy et al., 2021; Sartini et al., 2020; Singh et al., 2020; Thompson et al., 2020).

Although several studies have found conditions identified related to the patient's inability to continue the pronation position (tolerating the position) starting from discomfort in the position, patient uncooperativeness, worsening of oxygenation, desaturation, pain, and anxiety in the patient (Coppo et al., 2020; Winearls et al., 2020; Wormser et al., 2021). However, most studies show effective evidence for increasing oxygen saturation in patients with respiratory disorders after being given pronation position intervention. However, there has been no research linking the pronation position with mattress use or other assistive devices, especially if the pronation position is done independently. The independent pronation position has been recommended by providing additional pillows at several points on the body to adjust the body into a pronation position. Manual pronation

position by providing pillows is very vulnerable to causing positional inaccuracies due to differences in pillow size in each location, the possibility of the pillow shifting, differences in patient body size and weight, differences in patient perception regarding the description of the pronation position, differences in knowledge, level of education, age, and other characteristics.

The product innovation "Marning" was created as a tool to help carry out a pronation position that is comfortable, safe, does not require a lot of money, and is easy to implement for patients with complaints of shortness of breath because it does not cause side effects and can be done independently by the patient. Apart from that, this innovation was made by considering body size in anatomy and ergonomics. It is precisely sized so that it does not shift and is more comfortable when used independently by the patient. It is per several previous studies stated that one of the factors influencing the success of the pronation position is the patient's comfort factor (Paul et al., 2020). This research aims to create and develop a "marning" prototype to make it easier to carry out the prone position to increase oxygen saturation in patients with complaints of shortness of breath.

Method

The proning mattress is designed by considering the body's anatomical shape, ergonomics, and precise size and optimizing its function in increasing oxygen saturation. Mattresses are made with precision measurements by taking anthropometric and ergonomic measurements of the human body. Precision and ergonomics tests were carried out using measurements in the physiotherapy clinic laboratory on 20 respondents with various postures, both men and women, as a basis for determining mattress size. Anthropometric data measured were height, weight, thorax circumference in normal position, expiratory and inspiratory position, ankle joint angle, semiflexed knee angle, and semi-extended greater trochanter angle with a bed position of 45 degrees.

The anthropometric data obtained was then processed as a basis for making proning

mattress prototype sizes. The initial prototype was made by making a miniature size until an ergonomic shape was obtained, then it was made to the actual size to be used on patients with shortness of breath. The Marning prototype was tested on shortness of breath patients at the Pathuk I Gunung Kidul Community Health Center infectious clinic as a partner and pilot project for this research. The mattress effectiveness test was carried out on shortness of breath patients with oxygen saturation below 95%. The effectiveness test was carried out by measuring oxygen saturation in patients with complaints of shortness of breath before and after using the mattress. The research has received an ethics letter from the Ethics Committee of Aisyiyah University of Yogyakarta with number 2870/KEP-UNISA/V/2023

Results and Discussions

The research team created and developed (Marning), which is intended to make it easier for patients with complaints of shortness of breath to assume a pronation position to increase oxygen saturation. The result of this research is to obtain a mattress prototype for adjusting the proning position. The proning mattress is designed by considering the body's anatomical shape, ergonomics, and precise size and optimizing its function in increasing oxygen saturation. Mattress manufacturing takes into account precision measurements by taking into account the anthropometric measurements and ergonomics of the human body. Researchers conducted precision and body ergonomic tests on 20 respondents as a basis for determining mattress sizes, as shown in Table 1.

Table 1. Test Results on the Diversity of Anthropometric Measurements and Body Ergonomics of Proning Mattress Use by Respondents

Anthropometrics	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Height	20	15	150	165	156.20	4.82	23.3
Weight	20	48	50	98	67.25	12.9	167.8
Normal Thorax Circumference	20	30	86	116	98.30	7.78	60.6
Thorax Circumference (Inspiration)	20	29	89	118	100.95	8.03	64.5
Thorax Circumference (Expiration)	20	28	86	114	98.35	8.20	67.2
Ankle joint angle	20	20	40	60	45.00	5.84	34.2
Semiflexed knee angle	20	25	10	35	23.15	6.03	36.4
Semiextended major trochanter angle with 45 degrees bed position	20	20	15	25	18.50	3.15	9.9

(Source: Primary Data, 2022)

Based on the diversity of anthropometric measurements and body ergonomics of proning mattress respondents in Table 1, the research team designed precise measurements of proning mattresses to increase patient comfort and accuracy in carrying out the pronation position, as shown in Figure 1. Several research results show evidence related to increasing oxygen saturation in patients with complaints of shortness of breath with COVID-19 after being given pronation position intervention (Ashra et al., 2022; Caputo et al., 2020; Elharrar et al., 2020), but there are several conditions

identified related to the patient's inability to continue the pronation position (tolerating the position) include position discomfort, patient uncooperativeness, worsening oxygenation, desaturation, pain, and anxiety in the patient (Coppo et al., 2020; Winearls et al., 2020; Wormser et al., 2021). This discomfort is often associated with pillows that shift easily in manual proning techniques, so with this precision-sized mattress, it is hoped that patients will feel more comfortable without the fear of the pillow shifting.

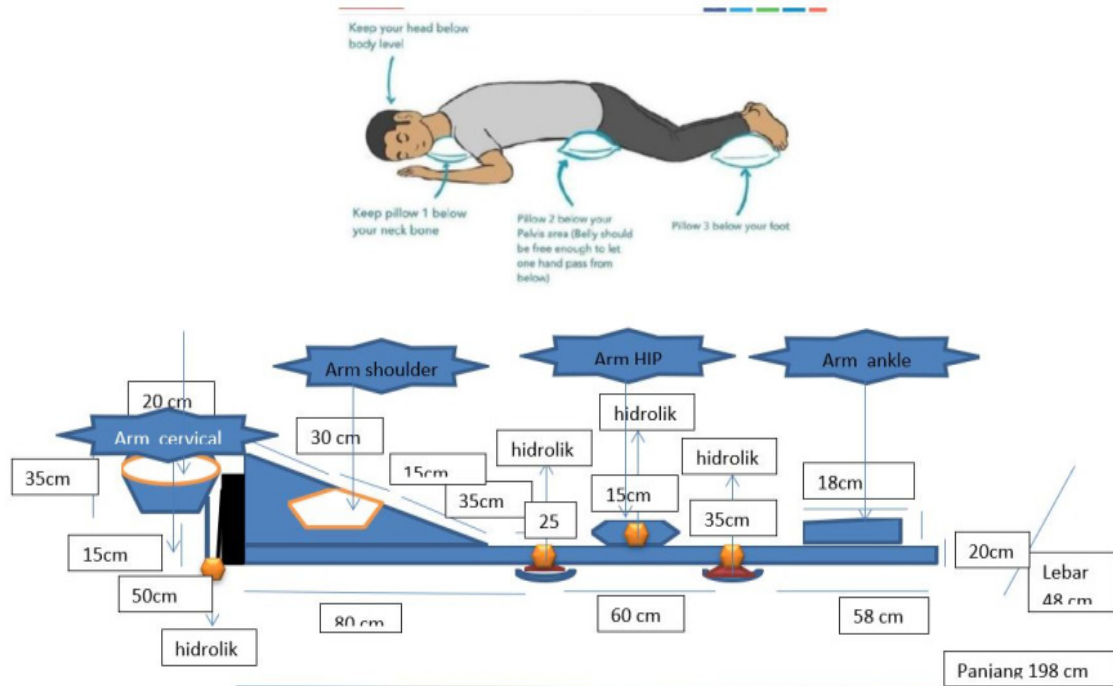


Image 1. Precise Size of Prone Mattress

The product innovation “Marning” is a tool to help carry out a pronation position that is comfortable, safe, does not require a lot of money and is easy to implement for patients with complaints of shortness of breath, does not cause side effects, and can be done independently by the patient. This technology model helps increase oxygen saturation in patients with complaints of shortness of breath and can be done independently by the patient without the

help of health workers. This innovation allows patients to assume a correct and comfortable pronation position. Marning has been designed considering the body’s anatomical shape and ergonomics. It is very effective and efficient because it can be used directly independently without arranging the pillow and can be folded. Making the distribution and storage easier as shown in Image 2.

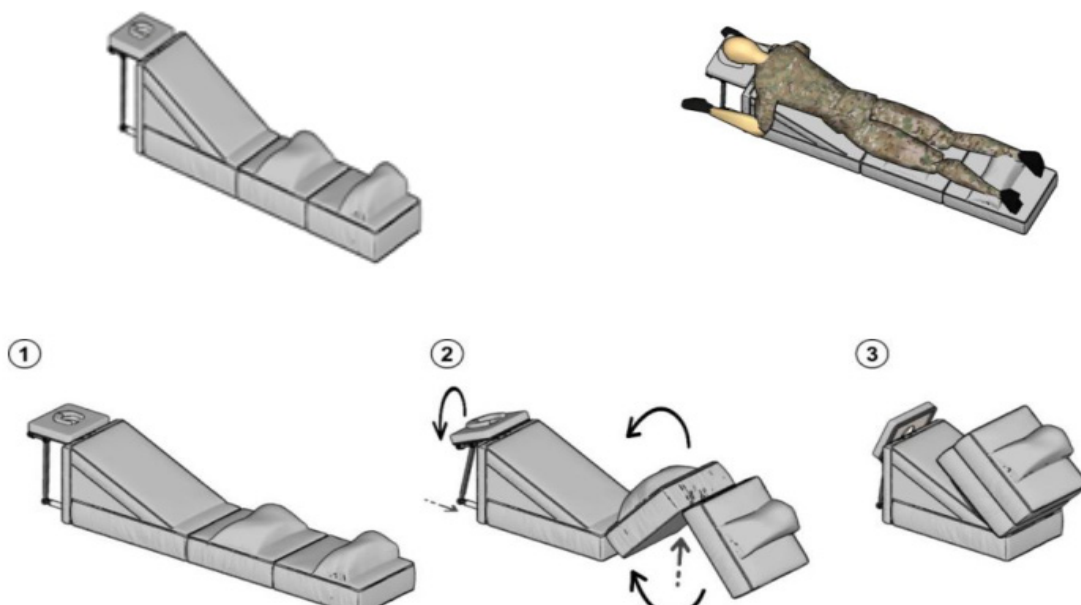


Image 2. Developed “Marning” (Prone Mattress) Product Design

This technology model has been successfully prototyped by the research team as shown in Figure 3. This prototype is intended to increase oxygen saturation in patients with respiratory disorders such as asthma, bronchitis, pneumonia, shortness of breath due to COVID-19, and shortness of breath due to other diseases. The mattress consists of a headrest section, support section, chest mattress section, stomach mattress section, and foot mattress section. The first part is the headrest, which is made in a square shape, where a hole is made in the middle surrounded by a sponge pad, where the headrest is placed

on a frame supported by a pole and connected to a hydraulic shaft. The headrest is made with holes to facilitate air circulation and reduce the possibility of breath being held by the mattress. Apart from that, by completing the holes in the headrest, the head position becomes more comfortable and ergonomic because it doesn't have to tilt to the left or right, and the respiratory tract is smoother. The Trendelenberg position during the proning position is more optimal than the flat position with the head turned to the right or left because the Trendelenberg position increases tidal volume and lung compliance. (Kodamanchili et al., 2022; Su et al., 2021).



Image 3. Prototype of “Marning” (Proning Mat)

Table 2. Description of the Effectiveness Test of Using a Proning Mattress to Increase Oxygen Saturation in Patients with Shortness of Breath

Respondents	Age (Years)	Gender	Diagnosa	SpO2 Before	SpO2 After	Follow-up
R1	70	Female	Breath shortness History of cardiac	94	93	Refer to hospital
R2	65	Male	Breath shortness History of hypertension	95	98	Can go home Polyclinic Control
R3	25	Female	Breath shortness Dypsnoea	95	95	Refer to hospital
R4	65	Male	Breath shortness	94	98	Can go home Polyclinic Control
R5	63	Male	Breath shortness with Chronic Obstructive Pulmonary Disease (COPD)	96	98	Can go home Polyclinic Control
R6	42	Female	Breath shortness, asthma	91	97	Nebulizer, get better Polyclinic Control
R7	55	Female	Dypsnoea	92	98	Can go home Polyclinic Control
R8	50	Female	Breath shortness, Fever, Epilepsy	94	98	Can go home Polyclinic Control

(Source: Primary Data, 2023)

The second part of the proning mattress is the support part, which is paired with the headrest and can be folded towards the support part through a hydraulic shaft. This section has a hydraulic pivot that allows it to be folded for easy storage and transport. The third part is the chest mattress section, which is equipped with a chest support, where the chest support is installed diagonally between the support section and the chest mattress section. This part of the chest mattress is reinforced with an iron frame that is strong enough to withstand the weight of Indonesian, in general. Apart from that, this chest mattress has a precise and comfortable size, making it possible to use it for quite a long time. The total duration of the proning position is 150 minutes-10 hours/day, with changes every 30 minutes-2 hours (Bentley et al., 2020).

The research team has tested the effectiveness of using mattresses to increase oxygen saturation in 9 respondents who suffer from shortness of breath of various ages, genders, and ages. The trial was carried out at the Pathuk I Gunung Kidul Community Health Center infectious clinic as a partner and pilot project for this research. Respondents who complained of shortness of breath had their oxygen saturation measured and were asked to use a proning mattress. After 30 minutes in the prone position, the respondent's oxygen saturation was measured again. The results of the mattress effectiveness test are shown in Table 2.

Based on the results of trials using a proning mattress on shortness of breath patients, 80% of shortness of breath patients experienced an increase in oxygen saturation after taking the prone position using a mattress. However, there are 20% whose oxygen saturation has not increased. This condition may be influenced by age, former smokers with a history of smoking ≥ 10 packs/year, diagnosis of shortness of breath, body mass index ≥ 30 kg/m², and C-reactive protein ≥ 5 mg/L, and history of other diseases such as hypertension and heart disease, which was significantly associated with decreased SpO₂ (Susanti et al., 2023; Vold et al., 2014).

Based on the use of mattresses by medical staff, several suggestions are that

manual hydraulics makes the preparation and adjustment to body size take longer. Apart from that, the tool is still quite large, so it is still a little elaborate to move and carry anywhere. It indicates that it needs to be refined in subsequent research. However, in terms of comfort, when used, patients tend to be more comfortable using the mattress and say the breath shortness is reduced.

The prone position is a technique used to help Acute Respiratory Distress Syndrome (ARDS) patients breathe (Hadaya & Benharash, 2020). P The 2013 Prone Positioning in Severe Acute Respiratory Distress Syndrome (PROSEVA) study showed that PP not only increased oxygenation but also reduced mortality in ARDS patients (Guérin et al., 2013). Although the safety of proning has long been a concern due to the risk of complications, more research is showing that when the PP maneuver is performed using standard protocols, and performed in the correct position, PP is very effective in increasing oxygen saturation (Athota et al., 2014; Benson & Albert, 2014; De Jong et al., 2013; Dirkes et al., 2012). Apart from appropriate positions and standards, several studies state that PP will be very effective and safe if carried out by trained and qualified staffs (Athota et al., 2014; Dirkes et al., 2012; Lee et al., 2014). Lastly, the effectiveness of PP is also influenced by the selection of the right patient, namely patients with respiratory problems without other complications (Gattinoni et al., 2013) then the position is safe and has minimal risk.

Several systematic review and meta-analysis results show the positive impact of PP in patients with non-invasive ventilation, including: significant improvement in oxygenation after PP with the PaO₂/FiO₂ ratio (mean difference -23.10; 95% confidence interval [CI]: - 34.80-11.39; P=0.0001; I²=26% (Fazzini et al., 2022); reduction in the need for intubation (Kang et al., 2022; Li et al., 2022); reduction in mortality (Fazzini et al., 2022; Kang et al., 2022). Results of PP research in COVID-19 patients with mild symptoms found that early proning position can relieve early hypoxia; shorten the length of stay and have a positive impact on clinical outcomes, in addition to the procedure being simple, safe

and clinically feasible, does not increase costs or workload for medical staff (Liu et al., 2021). This mattress innovation is very useful, as an effort to make it easier to adjust the prone position, which in turn can increase oxygen saturation in patients with respiratory problems.

Conclusion

The product innovation “Marning” is a tool to help carry out a pronation position that is comfortable, safe, does not require a lot of money, and is easy to implement in patients with respiratory problems such as COVID-19 or other respiratory problems. The mattress use allows for a longer time in the prone position with fewer side effects and can be done independently by the patient. This innovation provides patients to assume a correct and comfortable proning position and can be used immediately. Another advantage of this mattress is its precise size so it does not allow it to shift. This mattress is designed to replace pillows in common proning positions. The results of the proning mattress trial showed positive results, where 80% of respondents experienced an increase in oxygen saturation after 30 minutes of using the proning mattress. Unfortunately, the preparation time is still quite long because you have to rotate the hydraulics manually. Apart from that, the tool is still quite large. So it is still a little difficult to move and carry anywhere. It indicates that the development needs to be refined in subsequent research to get a tool that is lighter, easy to move, and carry anywhere.

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